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Acta Psychologica 119 (2005) 235–263
acta psychologica
www.elsevier.com/locate/actpsy

Measuring automatic retrieval: a comparison of implicit memory, process dissociation, and speeded response procedures

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Received 25 May 2004; received in revised form 20 January 2005; accepted 20 January 2005
Available online 25 March 2005

Abstract

Using the stem completion task, we compared estimates of automatic retrieval from an implicit memory task, the process dissociation procedure, and the speeded response procedure. Two standard manipulations were employed. In Experiment 1, a depth of processing effect was found on automatic retrieval using the speeded response procedure although this effect was substantially reduced in Experiment 2 when lexical processing was required of all words. In Experiment 3, the speeded response procedure showed an advantage of full versus divided attention at study on automatic retrieval. An implicit condition showed parallel effects in each study, suggesting that implicit stem completion may normally provide a good estimate of automatic retrieval. Also, we replicated earlier findings from the process dissociation procedure, but estimates of automatic retrieval from this procedure were consistently lower than those from the speeded response procedure, except when conscious retrieval was relatively low. We discuss several factors that may contribute to the conflicting outcomes, including the evidence for theoretical assumptions and criterial task differences between implicit and explicit tests.

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doi:10.1016/j.actpsy.2005.01.004

PsycINFO classification: 2340; 2343; 2380

Keywords: Memory; Automatic; Implicit memory; Process dissociation

1. Introduction

Several procedures have been developed in an attempt to identify the contributions to memory performance of automatic retrieval processes—retrieval of previously studied information with no intent to do so. These include implicit memory tasks (Graf & Schacter, 1985; Schacter, 1987), the retrieval intentionality criterion (Schacter, Bowers, & Booker, 1989), and the process dissociation procedure (Jacoby, 1991, 1998). The utility of each has been challenged on several grounds. For example, Jacoby (1991) and Richardson-Klavehn and Bjork (1988) noted that parallel effects of variables on implicit and explicit tests may indicate contamination of implicit performance with conscious retrieval. In terms of the retrieval intentionality criterion, Richardson-Klavehn, Gardiner, and Java (1996) argued that conscious retrieval is not a necessary consequence of awareness of the episodic history of an item (Graf & Komatsu, 1994; Roediger & McDermott, 1993). Finally, some of the theoretical assumptions of the process dissociation procedure have been questioned (e.g., Bodner, Masson, & Caldwell, 2000; Horton, Wilson, & Evans, 2001; Joordens & Merikle, 1993; Richardson-Klavehn et al., 1996).

Horton et al. (2001; Vonk & Horton, in press; Wilson & Horton, 2002) described an alternative procedure that uses RTs to identify retrieval strategy. The speeded response procedure is based on the assumption that automatic retrieval executes faster than conscious retrieval (de Houwer, 1997; Reingold & Toth, 1996; Richardson-Klavehn & Gardiner, 1995, 1996, 1998; Toth, 1996; Vaterrodt-Plünnecke, Krüger, & Bredenkamp, 2002; Weldon & Jackson-Barrett, 1993; Yonelinas & Jacoby, 1994), and we have reported data to support this assumption (Horton et al., 2001; Wilson & Horton, 2002). Following a study task, subjects in a speeded response group first received practice stem completion tests in which none of the stems corresponded to studied items. Their instructions were to respond as quickly as possible with the first word that came to mind. To increase response speed, average RTs were presented to subjects at the end of each test and faster responding was encouraged on the subsequent test. Because subjects were encouraged to respond quickly and no stems corresponded to the studied items, subjects had no basis for adopting conscious retrieval on the practice tests. These design features were implemented to maximize the likelihood that conscious retrieval strategies would be excluded. The critical stem completion tests immediately followed the practice tests with the only difference being that, on the critical test, 50% of the stems corresponded to studied items. Although it would be possible to switch to conscious retrieval on the critical tests, a comparison of speeded response group RTs with those from a baseline group and an explicit group argued against that conclusion.

Subjects in the baseline group performed exactly the same tasks as subjects in the speeded response group except that none of the stems on the critical test corresponded to previously studied items. The explicit group was treated the same as the speeded response group except that, immediately prior to the critical test, they were instructed to switch to a conscious retrieval strategy. That is, they were to use the stems to retrieve previously studied items while still responding as quickly as possible. The RTs on the critical test for the explicit group were longer than those of either the speeded response or the baseline group, which did not differ. Longer RTs for the explicit group compared to the baseline group are consistent with the assumption that conscious retrieval is slower than automatic retrieval (Richardson-Klavehn & Gardiner, 1995, 1996, 1998; Toth, 1996; Vaterrodt-Plünnecke et al., 2002). Critically, these findings also indicate that the speeded response group did not switch to a conscious retrieval strategy on the critical test.

In the present research, we extended this work to include a direct comparison of automatic estimates from the speeded response group with those from standard implicit and PDP groups. Depth of processing was manipulated in Experiments 1 and 2 and full/divided attention was manipulated in Experiment 3. A comparison of performance in the implicit condition with that of the speeded response group would indicate whether the standard implicit stem completion task is routinely contaminated with explicit retrieval. Similar automatic estimates in the speeded response and PDP conditions would provide converging evidence for the critical assumptions of these two measures of automatic retrieval.

2. Experiment 1

In Experiments 1 and 2, we used a depth of processing manipulation to compare estimates of automatic retrieval across implicit memory, PDP, and speeded response conditions. The stem completion task was used at test, as this has been frequently used in both implicit memory and PDP studies, and is particularly amenable to the speeded response task (Horton et al., 2001). In studies of implicit memory, deeper levels of processing invariably leads to greater priming, although these effects are not always reliable (Brown & Mitchell, 1994; Challis & Brodbeck, 1992; Newell & Andrews, 2004). By contrast, depth of processing consistently has no effect on the automatic component using PDP analysis (e.g., Jacoby, 1994; Jacoby, Toth, & Yonelinas, 1993).

We speculated that depth might have parallel effects on the automatic and conscious components of retrieval but that the effect on the automatic component was masked using PDP (Russo, Cullis, & Parkin, 1998). The logic for this hypothesis was twofold. First, PDP is based on the assumption that automatic and conscious retrieval are independent, which requires

$$p(A|\overline{C}) = p(A) = p(A|C)$$

where A refers to automatic retrieval and C refers to conscious retrieval. However, if automatic and conscious retrieval are positively correlated (Curran & Hintzman, 1995, 1997; Hintzman & Curran, 1997; Joordens & Merikle, 1993; Wilson & Horton, 2002; but see Jacoby, Begg, & Toth, 1997; Jacoby & Shrout, 1997), then use of the conditional probability $A|\overline{C}$ to estimate the unconditional probability A may result in an underestimate of A. Accordingly, PDP could lead to inaccurate conclusions about the effects of manipulations on automatic retrieval, particularly when the unconditional probability C is relatively high (Wilson & Horton, 2002). By contrast, if the independence assumption is correct, then A is accurately estimated by $A|\overline{C}$. Second, deeper processing could enhance automatic retrieval of the item, in addition to its effect on conscious retrieval. Such a finding is suggested by performance on implicit memory tasks, although performance on these tasks may be contaminated by conscious retrieval. Given that our speeded task invokes relatively pure automatic retrieval (Horton et al., 2001; Wilson & Horton, 2002), we can identify contamination from conscious retrieval on implicit tasks by directly comparing target completion rates in our speeded task with those in an implicit task. Contamination would be evidenced by higher target completion rates in an implicit task compared to the speeded group (Horton et al., 2001).

Experiment 1 included four groups: speeded response, implicit, inclusion, and exclusion. The speeded response group received three practice stem completion tests to maximize the likelihood of subjects generating completions based strictly on automatic retrieval in the critical test. The implicit group completed filler tasks prior to the critical stem completion task. The inclusion and exclusion groups also completed the filler tasks prior to completing word stems under either inclusion or exclusion instructions. Although inclusion and exclusion tasks have traditionally been given to the same subjects (for exceptions, see Dodson & Johnson, 1996; Hirshman, Fisher, Henthorn, Arndt, & Passannante, 2003; Jacoby, 1991; Jacoby et al., 1993; Russo & Andrade, 1995; Vaterrodt-Plünnecke et al., 2002), we opted for a between-subjects design to minimize concerns of subjects becoming confused about the tasks (Bodner et al., 2000; Buchner, Erdfelder, & Vaterrodt-Plünnecke, 1995; Curran & Hintzman, 1995; Graf & Komatsu, 1994).

2.1. Method

2.1.1. Subjects

A total of 60 university undergraduates participated in this research, either for bonus credit in their Introductory Psychology course or for $6. None of the students had previously participated in a similar study. Twelve students were randomly assigned to each group except that 24 students were assigned to the speeded response group. Some additional tests were conducted with subjects in the latter group after they had completed all aspects of the procedure described here. Because they did not differ on the tasks described here, we treat them as one group of 24 subjects. All subjects were tested individually.

2.1.2. Design

The design was a $4 \times 2 \times 4$ mixed factorial, with group (implicit, speeded response, inclusion, exclusion) as a between-subjects variable, and depth of processing (semantic, nonsemantic) and test (three practice tests, critical test) as within-subjects variables.

2.1.3. Materials

A total of 128 words were selected from the same source as used in Horton et al. (2001). The words were responses to 3-letter stems given by subjects who had not studied any words previously. The probability of generating the words varied from 0.05 to 0.20. All stems had several possible solutions but were unique within the list. Proper nouns and unusual or complex spellings were avoided.

Of these words, 72 served as practice word stems, 48 served as critical items, and 8 were buffer items in the study phase. The 48 critical items were randomly assigned to two lists of 24 items each. Half the subjects in each group studied each list. Of the 24 critical words in each list, 12 were studied in each of the semantic and nonsemantic orienting tasks. Over the course of the experiment, each item was studied equally often with each orienting task. The two orienting tasks were presented in randomized blocks in each study list. Four buffer items (two semantic, two nonsemantic) were presented at the beginning and the end of the study list, resulting in a total of 32 items in each list. Participants were exposed to all 48 critical stems on the critical test.

2.1.4. Procedure

Subjects were told that we were examining performance on a variety of tasks. During the study phase, all subjects studied half the words in the context of semantic orienting instructions and half in the context of nonsemantic orienting instructions using a block randomized order. In the semantic condition, subjects generated an associate for the word and verbalized that word to the experimenter. In the nonsemantic condition, subjects counted the number of consonants in each word and verbalized the number. The orienting instruction was presented in the top left corner of the computer screen and the target word was presented in the middle of the screen. The study trial was self-paced.

Following the study phase, subjects in the implicit group completed two filler tasks which required approximately the same length of time as the practice stem completion tasks given to other groups. Following the filler tasks, subjects completed the critical stem completion task under standard implicit memory instructions. Each stem appeared on the screen with instructions to verbalize the first word that came to mind that could complete the stem. Consistent with instructions used in other studies of implicit memory, there was not the emphasis on responding very quickly that there was in the speeded response group. Instructions for the stem completion task made no reference to the prior study trial.

Subjects in the inclusion and exclusion groups also completed the filler tasks immediately after the study trial and were then given instructions for the critical test. Instructions for the inclusion task indicated that approximately half the stems corresponded to studied words and that subjects were to use each stem to think of a studied word. If they could not think of a studied word, they provided the first word that came to mind. Subjects responded orally and the experimenter typed the response into the computer. Instructions for the exclusion task were similar to those for the inclusion task except for the emphasis on not responding with previously studied words.

Subjects in the speeded response group were given three practice tests followed by the critical test. The practice tests contained 12, 24, and 36 word stems, respectively.

Subjects were instructed to complete the stems as quickly as possible because their responses were being timed via a voice-activated relay. At the end of each practice test, the computer displayed the mean RT for that test and all previous practice tests. Throughout the practice tests, subjects were continually encouraged to increase their speed of responding. The critical test was presented immediately after the third practice test and was treated no differently by the experimenter than the practice tests. Responses to all stems were typed into the computer by the experimenter. No reference was made to the study phase at any stage during the stem completion tests.

2.2. Results

2.2.1. Response times

The RT data for the speeded response group appear in Table 1. Analysis of RTs on the three practice tests plus the nonstudied items on the critical test revealed a reliable effect, $F(3,69) = 8.57$, MSE = 13365. The RTs on the first test were significantly longer than those on each of the subsequent tests (LSD = 67 ms), but there were no differences among RTs on the final two practice tests and the critical test. A further analysis of the RT data on the final practice test and the nonstudied items on the critical test revealed no difference, $t(23) = 0.74$, SEM = 28.17. A power analysis was completed on these data in order to substantiate the conclusion that subjects in the speeded response group did not switch to a conscious retrieval strategy on the critical stem completion test. Horton et al. (2001) reported a RT difference of 1488 ms between the speeded response and baseline groups. We elected to use half that difference to assess the power of this test, recognizing that subjects must first become aware that they are generating studied items on the critical test before they can be expected to switch to a conscious strategy. Assuming a difference of 744 ms, the power of this test is greater than 0.99 ($d = 3.81$). A difference of 180 ms is required to

Table 1
Median RTs (in milliseconds) for the speeded response groups in Experiments 1, 1A, 2, and 3

	Practice Test 1	Practice Test 2	Practice Test 3	Critical Test: Nonstudied	Critical Test: Semantic/Full Attention	Critical Test: Nonsemantic/Divided Attention
Expt. 1	1027 (60)	891 (49)	879 (56)	930 (59)	908 (62)	885 (44)
Expt. 1A	964 (66)	913 (53)	–	915 (71)	837 (48)	881 (68)
Expt. 2	991 (66)	–	–	811 (67)	654 (31)	639 (31)
Expt. 3	891 (43)	803 (26)	785 (28)	751 (35)	678 (29)	757 (27)

Note: There were two practice tests in Experiment 1A and one in Experiment 2. Response times for the studied and nonstudied items on the critical stem completion test are shown separately. The semantic/nonsemantic manipulation was used in Experiments 1, 1A, and 2, and the full/divided attention manipulation was used in Experiment 3. Standard errors in parentheses.

satisfy the minimum requirements for a large effect ($d = 0.8$). Thus, consistent with the results of Horton et al., RTs for the speeded response group showed no evidence that subjects switched to a conscious retrieval strategy on the critical test, despite the presentation of stems from studied items on that test.

We analyzed RTs to stems for which the critical words were generated. Four subjects were deleted from this analysis because they failed to generate at least two target items on the critical test in one or both encoding conditions. The results appear in Table 1. There was no depth of processing effect, $F < 1$, although it may be noted that relatively few items were used in calculating these RTs for individual subjects, resulting in a large error term. This may account for the different statistical outcome here compared to that reported in Horton et al. (2001).

2.2.2. Stem completion

Based on the conclusion that responses of the speeded response group on the critical test reflect pure automatic retrieval, we can compare target completion rates of the implicit group with those of the speeded response group to determine if there is evidence that the implicit group also engaged in pure automatic retrieval. If target completion rates are similar, then it is reasonable to conclude that the implicit group did not use conscious retrieval. Higher target completion rates in the implicit group would suggest that their performance was contaminated by conscious retrieval. Similarly, automatic estimates from the inclusion and exclusion groups can be compared with those from the speeded response group to determine whether the PDP analysis provides good estimates of automatic retrieval. Baseline scores for the implicit group (0.13) and the speeded response group (0.14) did not differ, $F < 1$.

Target completion rates for the implicit and speeded response groups on the critical stem completion test appear in Table 2. Analysis of these data revealed no effect of group, $F < 1$, and no interaction of group × depth of processing, $F(1,34) = 1.18$, $\text{MSE} = 0.01$, indicating equivalent priming in the implicit and speeded response groups. Because the lack of difference between these two groups could be the result of a Type II error, we determined the power of a 2-tailed test ($\alpha = 0.05$) to detect a difference as large as that between the target completion rates in the implicit and inclusion groups (0.11). Using procedures described by Cohen (1988, Example 2.4), with $n' = 16$ and $d = 0.718$, power was approximately 0.76. There was a significant depth of processing effect, $F(1,34) = 15.58$, with higher target completion rates in the semantic than in the nonsemantic condition. This replicates the findings of Horton et al. (2001) and thus confirms that depth effects may be evidenced with automatic retrieval. The equivalent performance of the speeded response and the implicit groups suggests that the implicit group relied on automatic retrieval on the critical test and showed no evidence of contamination from conscious retrieval processes.

2.2.3. Analysis of PDP group data

Analysis of baseline scores revealed no reliable differences between the inclusion (0.18) and exclusion (0.14) groups, $F(1,22) = 1.45$, $\text{MSE} = 0.01$ (cf. Yonelinas & Jacoby, 1996). The target completion data for the PDP groups appear in Table 3. As expected, the inclusion group completed more stems with targets than did the

Table 2
Target completion rates for the implicit and speeded response groups in Experiments 1, 1A, and 2 as a function of encoding task

	Group	Encoding task		
		Semantic	Nonsemantic	Nonstudied
Expt. 1	Implicit	0.40	0.27	0.13
		(0.06)	(0.03)	(0.02)
	Speeded	0.37	0.28	0.14
	Response	(0.03)	(0.03)	(0.03)
Expt. 1A	Implicit	0.39	0.27	0.14
		(0.05)	(0.03)	(0.02)
	Speeded	0.36	0.29	0.12
	Response	(0.03)	(0.03)	(0.02)
Expt. 2	Implicit	0.62	0.57	0.39
		(0.03)	(0.02)	(0.02)
	Speeded	0.61	0.58	0.38
	Response	(0.03)	(0.02)	(0.02)

Standard errors in parentheses.

Table 3
Inclusion and exclusion scores, plus conscious and automatic estimates from the PDP groups, in Experiments 1, 1A, and 2 as a function of encoding task

	Measure	Model assumption	Encoding task	
			Semantic	Nonsemantic
Expt. 1	Inclusion		0.54	0.36
			(0.04)	(0.04)
	Exclusion		0.07	0.17
			(0.02)	(0.05)
	Conscious		0.46	0.19
	Automatic	Independence	0.14	0.21
		Redundancy	0.54	0.36
Expt. 1A	Inclusion		0.50	0.32
			(0.05)	(0.04)
	Exclusion		0.07	0.18
			(0.02)	(0.04)
	Conscious		0.43	0.14
	Automatic	Independence	0.12	0.21
		Redundancy	0.50	0.32
Expt. 2	Inclusion		0.72	0.67
			(0.03)	(0.02)
	Exclusion		0.51	0.51
			(0.05)	(0.05)
	Conscious		0.20	0.16
	Automatic	Independence	0.65	0.60
		Redundancy	0.69	0.61

Automatic estimates are shown for the independence and redundancy assumptions. Conscious estimates are the same across the two model assumptions. Standard errors in parentheses.

exclusion group, $F(1,22) = 74.07$, MSE = 0.02. There was no overall depth effect, $F(1,22) = 1.52$, MSE = 0.02, however, there was a substantial interaction of group by depth, $F(1,22) = 14.37$, indicating that semantically encoded items were more accurately included by the inclusion group and were more accurately excluded by the exclusion group, than were nonsemantically encoded items.

We derived estimates of conscious and automatic retrieval from the PDP groups using the independence assumption (Buchner et al., 1995),

$$C = I - E$$

$$A = \frac{E}{(1 - C)}$$

where I and E refer to target completion rates on the inclusion and exclusion tasks, respectively. The estimate of the variance of the sampling distribution for automatic retrieval when inclusion and exclusion tasks are manipulated between subjects was based on Horton and Vaughan (1999).[1] Conscious estimates were higher following the semantic task than following the nonsemantic task, $t(22) = 2.65$, SEM = 0.10, but automatic estimates based on the independence assumption did not show a depth effect, $t(22) < 1$, SEM = 0.09. These findings parallel those reported previously (Jacoby et al., 1993; but see Richardson-Klavehn & Gardiner, 1998).

The independence relationship adopted by the PDP model is only one possible relationship between automatic and conscious processes. Joordens and Merikle (1993; Curran & Hintzman, 1995; see also Bodner et al., 2000; Wilson & Horton, 2002) offered arguments for a redundancy assumption which specifies that, "whenever a conscious influence is present, there is also a correlated unconscious influence" (Joordens & Merikle, 1993, p. 464). Calculation of the conscious influence remains unchanged with this assumption (Buchner et al., 1995), however, automatic influences are equated with performance on the inclusion test. Automatic estimates based on the redundancy assumption were reliably higher in the semantic than in the nonsemantic condition, $t(22) = 2.47$, SEM = 0.07. Thus, the independence assumption leads to the conclusion that the automatic estimate was not affected by depth of processing, although it yielded a numerically higher estimate in the nonsemantic condition. By contrast, the redundancy model revealed a reliably higher automatic estimate in the semantic condition (see also Hirshman et al., 2003).

[1] The derivation of the estimate of the variance of the sampling distribution of ratios is based on Cochrane (1977) and Stuart and Ord (1987), and is detailed in Horton and Vaughan (1999). The estimates of the variances of the sampling distributions for the conscious and automatic estimates are given by the equations,

$$S^2_{\overline{C}} = S^2_{\overline{I}} + S^2_{\overline{E}}$$

$$S^2_{\overline{A}} = \frac{1}{\overline{X}^4_{1-C}}\left[\frac{S^2_E}{n_E}(1-\overline{X}_I)^2 + \frac{S^2_I}{n_I}(\overline{X}^2_E)\right]$$

where A and C refer to the automatic and conscious estimates and I and E refer to inclusion and exclusion scores.

2.2.4. Comparison of speeded response and PDP groups

In the final analyses, we compared estimates of automatic retrieval from the speeded response group with those from the inclusion and exclusion groups using each retrieval assumption (independence, redundancy). Baselines were not subtracted in these analyses, following the convention for deriving these estimates. For the independence model, the analysis included data for 24 subjects in the speeded response group and for 12 subjects in each of the inclusion and exclusion groups. For the redundancy model, the analysis included data for 24 subjects in the speeded response group and 12 subjects in the inclusion group.

Using the independence assumption, the speeded response group provided a reliably higher estimate of automatic retrieval than did the PDP groups for semantically encoded items, $t(46) = 3.31$, SEM = 0.07. Using the redundancy assumption, the PDP groups yielded a higher estimate of automatic retrieval in the semantic condition than did the speeded response group, $t(34) = 2.36$, SEM = 0.07, but estimates of automatic retrieval in the nonsemantic conditions did not differ regardless of whether independence or redundancy was assumed, t's = 0.91 and 1.18, SEMs = 0.08 and 0.07, respectively. It is notable that, in the nonsemantic as in the semantic condition, the pattern of data indicated that the independence assumption underestimated automatic retrieval relative to the speeded response group whereas the redundancy assumption yielded an overestimate, although none of the differences for the nonsemantic condition were reliable (see also Horton et al., 2001).

2.3. Discussion

Experiment 1 provided a comparison of automatic estimates following a depth of processing manipulation. The results of the study are straightforward. First, the RT data from the speeded response group replicated those of Horton et al. (2001) in showing no evidence of subjects switching to a conscious retrieval strategy when stems of studied words were presented on the critical stem completion test. The pattern of RTs did not change from the practice tests to the critical test, consistent with the conclusion that subjects relied on automatic retrieval for the critical test, rather than switching to conscious retrieval.

Target completion rates and depth of processing effects in the implicit and speeded response groups were identical, suggesting that the implicit group also relied on automatic retrieval to perform the implicit task. Although depth effects on implicit memory tasks have been interpreted as evidence of contamination by conscious retrieval (Jacoby et al., 1993; Jenkins, Russo, & Parkin, 1998; Toth, Reingold, & Jacoby, 1994), the present findings suggest that these effects may be mediated entirely by automatic retrieval.

Notably, the PDP estimates of automatic retrieval using the independence assumption underestimated those provided by the speeded response and implicit groups, at least in the semantic encoding condition. These findings are consistent with the hypothesis that automatic and conscious retrieval are correlated rather than independent processes (Curran & Hintzman, 1995, 1997). Assuming that the speeded response group provided estimates of A through their responses on the critical test and noting that for an independence-based PDP, A is estimated as $A|\overline{C}$, the lower estimates provided by the PDP groups suggest that $A|\overline{C} < A$, necessitating that $A|\overline{C} < A|C$. Given that C is greater for items encoded semantically versus nonsemantically, this also accounts for the finding that the estimate of A derived from the speeded response group is reliably larger than that from the PDP groups in the semantic condition, but not in the nonsemantic condition (see also Wilson & Horton, 2002).

A followup experiment was designed to achieve a more statistically powerful test of these ideas. We only briefly summarize this experiment here as it largely replicates the procedure of Experiment 1. We reduced the number of practice tests in this followup study to two (16 and 32 items, respectively). Sixteen subjects were tested in each of three groups (implicit, inclusion, exclusion) and 32 subjects were tested in the speeded response group. In all other regards, the experiment was identical to Experiment 1. The RT data for this experiment (Experiment 1A) appear in Table 1. The target completion data and PDP estimates appear in Tables 2 and 3, respectively. The results of the experiment confirmed each of the effects found in Experiment 1, including no change in the pattern of RTs from the practice tests to the critical test in the speeded response group (power > 0.99 to detect a 744 ms difference between the second practice test and the nonstudied items on the critical test, $d = 3.78$). In addition, target completion rates did not differ between the implicit and speeded response groups. The power of a 2-tailed test ($\alpha = 0.05$) to detect a difference between these two groups that was as large as the difference in target completion rates between the implicit and inclusion groups (0.08; $n' = 21$, $d = 0.537$) was .66. Combining the data from Experiments 1 and 1A provided a much stronger test: The power to detect a difference as large as that between the implicit and inclusion groups (0.096; $n' = 37$, $d = 0.641$) was 0.97, although there was no effect, $F < 1$. As in Experiment 1, the independence-based PDP groups yielded a large underestimate of automatic retrieval in the semantic condition relative to the speeded response group, although this effect was not evident in the automatic estimates in the nonsemantic condition. In addition, the depth effects reported above were replicated.

3. Experiment 2

A potentially important concern from the results of Experiment 1 is that a relatively large number of subjects performed perfectly on the exclusion task, particularly in the semantic encoding condition. This "exclusion = 0 problem" ($E = 0$) (Curran & Hintzman, 1995) has been identified as a potential problem in that estimates of A (and C) may reflect floor effects rather than legitimate effects of variables (Curran & Hintzman, 1997; Jacoby, 1998; Jacoby et al., 1997). Although the PDP conditions in Experiment 1 replicated the lack of effect of the depth of processing manipulation reported previously (Jacoby et al., 1993; Toth et al., 1994), the lower estimates of A in these conditions relative to the speeded response group may be the result of a relatively large percentage of $E = 0$ scores in our exclusion group.

In order to minimize the number of $E = 0$ scores, we replicated Experiment 1 using materials with a higher baseline and in all other regards we followed the procedures recommended by Jacoby (1998) as closely as possible. However, we elected not to use the materials recommended by Jacoby because subjects are restricted to 5-letter responses. Our speeded response procedure does not lend itself to this restriction because quickly coming up with a 5-letter response would be extremely difficult for at least some items, most notably those with very high normative baseline rates. The risk, then, would be that subjects would sacrifice speed, and perhaps switch to a conscious retrieval strategy, thereby offsetting the benefits of our procedure (Horton et al., 2001). We followed the recommendation of a longer study list (68 words vs. 32 words in Experiment 1) and a longer test list (90 stems vs. 48 stems). Each was expected to help reduce the number of $E = 0$ scores. We presented just one practice test of 30 nonstudied stems to the speeded response group because of limitations on the pool of items.

Two other issues were also addressed in Experiment 2. First, the trend to higher automatic estimates (based on the independence calculations) in the nonsemantic condition could be the result of more perceptual processing during the study trial if this task requires more time to complete than the semantic task. In order to determine if study time differences exist between the two tasks, we measured how long subjects required to complete each task.

Second, subjects in the nonsemantic condition may have failed to complete lexical analysis of every item (Lee, 2002; Richardson-Klavehn & Gardiner, 1998; Weldon, 1991), which could account for the lower target completion rate in the nonsemantic condition in the implicit and speeded response groups. That target completion rates in the nonsemantic condition were measurably above baseline could be due to lexical processing of some of these items. Therefore, in Experiment 2, subjects verbalized all items during the study trial, a strategy that has been used in some (e.g., Jacoby, 1998) but not all PDP studies (e.g., Toth et al., 1994) to ensure lexical access.

3.1. Method

3.1.1. Subjects

A total of 89 university undergraduates participated for credit in an Introductory Psychology course. None of the students had previously participated in a similar study. Twenty-two students were randomly assigned to each group, except that the exclusion group included 23.

3.1.2. Design

The design was a $4 \times 2 \times 4$ mixed factorial, with group (implicit, speeded response, inclusion, exclusion) as the between-subjects variable, and depth of processing (semantic, nonsemantic) and test (practice test, critical test) as within-subjects variables.

3.1.3. Materials

The critical stimuli were 120 words from a normative sample collected in our lab. The stems for these words yielded target completion rates varying from 0.27 to 0.70

in the normative data, with a mean of 0.39. A further eight words from the same pool were selected for buffer items on the study trial.

For the study trial, 60 words were randomly selected from the original pool of 120 words. Subjects saw 30 words in each of the semantic and nonsemantic conditions, presented in randomized blocks. Four buffer items (two semantic, two nonsemantic) were presented at the beginning and end of the study list. Thus, a total of 68 items were presented in the study list. For the critical test, participants were exposed to the stems for all 60 critical items along with stems of 30 randomly selected nonstudied words. Subjects in the speeded response group were presented the stems from the remaining 30 words on the practice test.

3.1.4. Procedure

The procedure for the study trial was very similar to that of Experiment 1 in terms of instructions, screen display, and timing of events. The notable differences were that subjects verbalized the word on the screen prior to giving their response to the semantic or nonsemantic task, and subjects verbalized their response to the encoding task prior to entering a response on the keyboard.

Following the study phase, subjects in the implicit, inclusion, and exclusion groups completed a filler task and then completed the critical stem completion test under the same conditions as the corresponding groups in Experiment 1. Subjects in the speeded response group were given one practice stem completion test of 30 stems followed by the critical test. The remaining features of the stem completion task replicated those of Experiment 1 except that all groups entered their responses on the keyboard after verbalizing their response. Responses were tape recorded for comparison to the typed responses.

3.2. Results

3.2.1. Response times

The first analysis addressed the role of study time on automatic estimates. In Experiment 1, the higher automatic estimates in the nonsemantic than in the semantic condition for the PDP groups could be the result of longer exposure to the stimulus in the nonsemantic task, thereby enhancing the perceptual processing that supports priming in the stem completion task (Roediger, Weldon, Stadler, & Riegler, 1992). The analysis included data for all four groups. Median RTs were significantly longer in the semantic than in the nonsemantic condition (2586 vs. 1662 ms, respectively), $F(1,85) = 81.96$, MSE = 463,342, but there was no effect of either group or the interaction, both F's < 1. Thus, greater exposure time to items in the nonsemantic condition cannot account for higher automatic estimates in this condition.

Median RTs for the speeded response group were faster on the baseline items of the critical test than on the practice trial, $F(1,21) = 14.14$, MSE = 25,336. Thus, there was no evidence that this group switched to a conscious retrieval strategy on the critical test. The data appear in Table 1.

Analysis of median RTs to stems for which subjects in the speeded response group generated the target item on the critical test revealed no depth effect, $F < 1$, replicating the results from Experiment 1. These RTs were based on a minimum of 11 correct responses for each subject in each of the semantic and nonsemantic conditions.

3.2.2. Stem completion

The speeded response and implicit groups did not differ in the proportion of baseline items completed with targets on the critical test, $F < 1$. The baseline rate of completion with the target response was approximately 0.38 for both groups, indicating that the new materials had the desired effect of raising baselines to the level used by other researchers (Jacoby, 1998).

Analysis of target completion rates for the speeded response and implicit groups revealed a small but reliable depth of processing effect, $F(1,42) = 5.76$, MSE = 0.01, but no effect of group or the interaction of group × depth of processing, both F's < 1. The reduced depth effect, compared to Experiment 1, is most likely due to requiring lexical analysis of the study word (Richardson-Klavehn & Gardiner, 1998).

3.2.3. Analysis of PDP group data

Baseline rates did not differ in the inclusion and exclusion groups (0.37 and 0.32), $F(1,43) = 2.69$, MSE = 0.01. The inclusion group completed more stems with targets than did the exclusion group, $F(1,43) = 14.55$, MSE = 0.08. Neither the depth effect, $F(1,43) = 2.09$, MSE = 0.01, nor the interaction of group by depth was reliable, $F(1,43) = 1.39$. The lack of depth effect and the lack of an interaction of group × depth are likely also attributable to the lexical analysis required to verbalize the study words. When verbalization is not required, as in Experiment 1 and in Toth et al. (1994, Experiment 1), depth effects occur on inclusion and exclusion tasks.

The key purpose of using a different set of materials in Experiment 2 was to minimize the number of subjects with $E = 0$ scores. In Experiment 2, only 2 of 23 subjects obtained $E = 0$ scores and none had perfect inclusion scores.

Conscious and automatic estimates in the PDP group were derived using the independence and redundancy assumptions. Conscious estimates yielded a reliable depth effect, $t(41) = 2.48$, SEM = 0.02, as did automatic estimates based on the independence assumption, $t(41) = 4.51$, SEM = 0.01. A larger numerical difference in automatic estimates based on the redundancy assumption was offset by greater variability, resulting in no depth effect, $t(41) = 1.82$, SEM = 0.03. Conscious estimates in Experiment 2 replicated the depth effect reported in Experiment 1, although the magnitude of the effect was much smaller due to the much lower conscious estimate in the semantic condition. The pattern of the automatic estimates deviated from that in Experiment 1 where estimates based on the independence assumption revealed no depth effect but estimates based on the redundancy assumption did reveal a depth effect. The markedly higher automatic estimates in Experiment 2 compared to Experiment 1 are attributable to the higher baseline rates in Experiment 2.

3.2.4. Comparison of speeded response and PDP groups

Analyses of the automatic estimates based on the independence assumption indicated no difference between the speeded response and PDP groups on semantic or nonsemantic items, t's(42) = 1.22 and 1.64, SEMs = 0.03 and 0.02, respectively.

Similarly, analyses of the automatic estimates based on the redundancy assumption indicated no difference between groups on semantic or nonsemantic items, t's(42) = 1.50 and 1.32, SEMs = 0.04 and 0.03, respectively.

3.3. Discussion

Experiment 2 was designed to resolve three issues. First, the higher automatic estimates observed in the nonsemantic condition in Experiment 1 could be due to subjects spending more time completing this task than the semantic task. Using exactly the same tasks (albeit with the additional requirement of verbalizing the study word), Experiment 2 showed that the task of counting consonants actually took less time than generating associates. Therefore the higher automatic estimates observed in the nonsemantic condition in the PDP groups of Experiment 1 cannot be attributed to longer exposure to the study word.

A second issue was whether the depth effect observed in the target completion rates for the speeded response and implicit groups could be attributed to a failure to complete lexical processing of at least some study words in the nonsemantic condition (Richardson-Klavehn & Gardiner, 1998). Experiment 2 provided support for this hypothesis, as the depth effect was markedly reduced when lexical processing was required of all words. Nonetheless, a small but reliable depth effect remained in the target completion rates, suggesting that deficits in lexical processing do not fully account for depth effects in automatic estimates. Richardson-Klavehn and Gardiner required subjects to complete a lexical decision task on each studied item (some word-like nonwords were included in the study list) and found no depth effect in target completion rates. The additional requirement of the lexical decision task, beyond simple identification of the word, may offset the depth effect on the stem completion test.

By selecting items with a higher baseline, we substantially reduced the number of subjects with $E = 0$ scores in the exclusion group, compared to Experiment 1. Other effects of the higher baseline were as expected. In the speeded response and implicit groups, target completion rates increased in the two study conditions, and all were well above baseline. Some of the increase in the nonsemantic condition was likely due to the lexical processing requirement. In addition, target completion rates were higher in the inclusion group and markedly higher in the exclusion group. The latter reflected strictly the increase in baseline as these target completion rates were only minimally above baseline, replicating the pattern reported in Experiment 1.

The differential effect of the change in materials on the inclusion and exclusion data had predictable effects on conscious and automatic estimates. Conscious estimates declined substantially in the semantic condition, relative to Experiments 1 and 1a, as would be expected with the longer study and test lists used in Experiment 2. In the nonsemantic condition, there was little effect of the change of materials on conscious estimates. The advantage of the lexical processing carried out on the study trial may have been offset in this condition by the longer study and test lists.

In contrast to the effect on conscious estimates, automatic estimates increased relative to those in Experiment 1, and more so for calculations based on the independence assumption than for those based on the redundancy assumption. The effect of lower conscious estimates on automatic estimates is predictable if conscious and automatic retrieval are correlated processes. Based on the equation

$$A = (A|C)^{*}C + (A|\overline{C})^{*}\overline{C}$$

Wilson and Horton (2002) noted that as conscious estimates decrease, automatic estimates derived from the independence assumption will increasingly approximate the unconditional probability A because the latter will increasingly be weighted as the conditional probability $A|\overline{C}$. Our data show this relationship: Conscious estimates decreased, relative to Experiment 1, and automatic estimates derived from the independence calculations based on the inclusion and exclusion groups were virtually identical to those from the speeded response groups in both the semantic and nonsemantic conditions. Further, automatic estimates based on the redundancy model were virtually identical to those based on the independence model. Overall, this pattern suggests that conscious and automatic retrieval are correlated processes.

4. Experiment 3

The third experiment provided a further comparison of measures of automatic retrieval. Jacoby et al. (1993; Debner & Jacoby, 1994; Jacoby, 1998) found that full versus divided attention at study had no impact on automatic estimates, although there was a substantial effect of this manipulation on conscious estimates (see also Schmitter-Edgecombe, 1999). It seems possible, however, that dividing attention at study reduces encoding of information that supports automatic as well as conscious retrieval (see also Joordens & Merikle, 1993). This would be expected if automatic and conscious retrieval are correlated processes, as suggested by our previous findings and those of other researchers (e.g., Bodner et al., 2000; Curran & Hintzman, 1995).

There is abundant evidence that performance on most perceptual implicit memory tests is not impaired by dividing attention, although there are exceptions to this pattern (see Mulligan, 1998, for a summary). For the stem completion test, however, the limited evidence is equivocal (Clarys, Isingrini, & Haerty, 2000; Gabrieli et al., 1996, cited in Mulligan, 1998; Schmitter-Edgecombe, 1999), although the finding of an attention effect may be related to the difficulty of the secondary task (Wolters & Prinsen, 1997). However, our interest is in whether, under conditions of full and divided attention, the speeded response group would provide an estimate of automatic retrieval that parallelled that of the implicit group or the estimates derived from the PDP groups or neither.

4.1. Method

4.1.1. Subjects

A total of 96 university undergraduates participated either for bonus credit in their Introductory Psychology course or for $6. None of the students had previously participated in a similar study. Twenty-four subjects were randomly assigned to each of the four groups and tested individually.

4.1.2. Design

The design was a $4 \times 2 \times 4$ mixed factorial, with group (implicit, speeded response, inclusion, exclusion) as the between-subjects variable, and attention at study (full, divided) and test (3 practice tests, critical test) as within-subjects variables.

4.1.3. Materials and procedure

The materials and procedure were identical to those of Experiment 1 with the following exceptions. First, the study trial was presented as two distinct lists from the subject's perspective, with full and divided attention conditions assigned equally often to the first and second lists. Items were counterbalanced across the attention manipulation. Second, because of the separation of the two attention conditions, 12 words were used as study buffers, with 3 at the beginning and 3 at the end of each list. Third, a list of single-digit numbers was digitized for auditory presentation. This list contained approximately 60% odd numbers. In the divided attention condition, the numbers were presented in random order at a 1 s rate, with two numbers presented prior to the first study word and two numbers presented after the last study word. The subject's task was to read the words while simultaneously attempting to identify sequences of three consecutive odd numbers. In the full attention condition, subjects were instructed to read the words without the distraction of the numbers. Words were presented at a 3 s rate.

4.2. Results

4.2.1. Response times

Response times for nonstudied items in the speeded response group on each of the four stem completion tests appear in Table 1. Analyses indicated that RTs varied over tests, $F(3,69) = 9.44$, MSE = 9564. The RTs on the first test were significantly longer than those on each subsequent test (LSD = 56 ms). Further analysis of RTs on the final practice test and the nonstudied items on the critical test yielded an effect that approached significance, $t(23) = 1.98$, SEM = 19.88, but the effect is in the opposite direction to that anticipated if subjects switched to a conscious retrieval strategy. Assuming a difference of 744 ms, as in Experiment 1, the power to detect a reliable increase in RTs is greater than 0.99 ($d = 5.40$). A difference of 128 ms is required to satisfy the minimum requirements for a large effect ($d = 0.8$). Thus, consistent with the results of Experiment 1, RTs showed no evidence that subjects in the speeded response group switched to a conscious retrieval strategy on the critical test.

An analysis was conducted on RTs for only those stems to which the subject generated the target word on the critical test. Three subjects were deleted from this analysis because they failed to generate at least two target items on the critical test in each encoding condition. The analysis revealed a reliable effect of study condition, $F(2,40) = 6.15$, MSE = 6450, with faster RTs for items in the full attention condition than for items in either the divided attention condition or the nonstudied condition (LSD = 54 ms). The latter two conditions did not differ reliably. The relative instability of these data suggest caution in interpreting these data.

4.2.2. Stem completion

Target completion and baseline data for the implicit and speeded response groups appear in Table 4. Analysis of the baseline data revealed no difference between these two groups, $F < 1$.

Analysis of the target completion data revealed no difference between the implicit and speeded response groups, $F(1,46) = 1.17$, MSE = 0.02, and no interaction of group × study task, $F < 1$. The power of a 2-tailed test ($\alpha = 0.05$) to detect a difference between the implicit and speeded response groups as large as the difference in target completion rates between the implicit and inclusion groups (0.10; $n' = 24$, $d = 0.694$) was 0.87. The target completion rate was greater in the full than in the divided attention condition, $F(1,46) = 24.30$, MSE = 0.02, consistent with the hypothesis that the full attention condition provided more information that was both available and useable on the stem completion test than did the divided attention condition.

4.2.3. Analysis of PDP group data

The data for the PDP groups appear in Table 5. The baseline scores of the inclusion (0.15) and exclusion (0.12) groups did not differ reliably, $F(1,46) = 1.63$, MSE = 0.01. Dividing attention resulted in a large reduction in the number of targets produced by the inclusion group and no difference in the number of targets produced by the exclusion group. There was a significant effect of group, $F(1,46) = 48.48$, MSE = 0.02, a significant effect of full versus divided attention, $F(1,46) = 11.56$, MSE = 0.02, and a reliable interaction, $F(1,46) = 15.04$.

Four of the 24 subjects in the exclusion group had perfect scores ($E = 0$). Analysis of the conscious estimates for the PDP groups revealed a reliable advantage of full versus divided attention, $t(46) = 2.48$, SEM = 0.09. Automatic estimates did not differ for full and divided attention conditions when calculated based on the independence assumption, $t(46) = 1.37$, SEM = 0.04, however, there was a reliable advantage for the full attention condition when automatic estimates were based on the redundancy assumption, $t(46) = 2.99$, SEM = 0.07. The results based on the independence

Table 4
Target completion rates for the implicit and speeded response groups in Experiment 3 as a function of attention condition at study

Group	Attention		
	Full	Divided	Baseline
Implicit	0.40 (0.03)	0.25 (0.02)	0.13 (0.02)
Speeded Response	0.42 (0.04)	0.30 (0.03)	0.13 (0.02)

Standard errors in parentheses.

Table 5
Inclusion and exclusion scores, and conscious and automatic estimates from the PDP groups, in Experiment 3 as a function of full versus divided attention at study

Measure	Model assumption	Attention	
		Full	Divided
Inclusion		0.54 (0.04)	0.32 (0.03)
Exclusion		0.19 (0.03)	0.20 (0.02)
Conscious		0.35	0.12
Automatic	Independence	0.29	0.23
	Redundancy	0.54	0.32

Automatic estimates are shown for the independence and redundancy assumptions. Conscious estimates are the same across the two model assumptions. Standard errors in parentheses.

assumption replicate those of previous researchers (Debner & Jacoby, 1994; Jacoby et al., 1993; Schmitter-Edgecombe, 1999; Wolters & Prinsen, 1997).

4.2.4. Comparison of speeded response and PDP groups

For the full attention condition, the speeded response group yielded higher automatic estimates than did the PDP groups based on the independence assumption, $t(70) = 2.31$, SEM = 0.06. Using the redundancy assumption, the automatic estimate from the PDP groups was numerically, but not reliably, larger than the estimate from the speeded response group, $t(46) = 1.48$, SEM = 0.08. For the divided attention condition, there was no reliable difference in the automatic estimates between the speeded response group and the PDP groups when the automatic estimates in the latter group were based on independence, $t(70) = 1.52$, SEM = 0.05, or redundancy, $t(46) = 0.40$, SEM = 0.05.

4.3. Discussion

The RT data indicated that the speeded response group did not change to a conscious retrieval strategy on the critical test. Also, both the speeded response and the implicit groups showed greater priming under full than divided attention. This effect was equivalent in the two groups, suggesting that the implicit group employed strictly automatic retrieval to complete stems on the critical test.

Whereas the effects of full and divided attention on the PDP estimates of conscious and automatic retrieval parallelled those of previous studies (Debner & Jacoby, 1994; Jacoby et al., 1993; Schmitter-Edgecombe, 1999; Wolters & Prinsen, 1997), the automatic estimates from our PDP groups were reliably lower than those from the speeded response group in the full attention condition. By contrast, under conditions that allowed for relatively little conscious retrieval, namely divided attention at study, the PDP estimates of automatic retrieval were similar to those derived from the speeded response group (Wilson & Horton, 2002).

Three concerns arose from Experiment 1, each of which was addressed in Experiment 2. We briefly consider these here in the context of Experiment 3. First, unlike in Experiment 1, differential exposure to stimuli at study was not an issue in Experiment 3 as study words were presented for a fixed interval in both conditions. Second, as Experiments 1 and 3 were conducted at the same time, we did not require verbalization of study words in Experiment 3 either, and therefore we cannot confirm that subjects completed sufficient lexical processing of every study word to support automatic retrieval. However, subjects in Experiment 3 were instructed to read the words (not overtly) rather than perform a nonsemantic encoding task that might induce them to focus on only certain letters rather than the entire lexical unit. Finally, the number of $E = 0$ scores was not a serious concern in this experiment as only four exclusion subjects provided perfect scores. Analysis of the data with and without these four subjects yielded the same statistical outcomes.

5. General discussion

5.1. Evidence for automatic retrieval

Previous attempts to isolate automatic retrieval have met with various criticisms. Horton et al. (2001) and Wilson and Horton (2002) compared performance of a speeded response group with those of both an explicit group given explicit retrieval instructions and a baseline group in which no critical stems could be completed with studied items. The time to generate completions on the critical stem completion test was reliably greater in the explicit group than in either the speeded response or the baseline groups, which did not differ. The longer RTs in the explicit group than in the baseline group confirm that conscious retrieval takes longer to complete than automatic retrieval (Richardson-Klavehn & Gardiner, 1995, 1998). The RTs in the speeded response group were equivalent to those in the baseline group and faster than those in the explicit group, indicating that the speeded response group did not switch to a conscious retrieval strategy when presented stems of previously studied items (Richardson-Klavehn, Clarke, & Gardiner, 1999; Richardson-Klavehn & Gardiner, 1998). The RT data from all three experiments reported here lead to exactly the same conclusion.

In drawing this conclusion, it is useful to identify exactly how we define automatic retrieval. We have suggested previously (Horton et al., 2001) that our interpretation of automatic retrieval would allow us to use the label *unintentional retrieval* because we focus on the nature of the cognitive operations that subjects enlist for completing the task. We restrict our operational definition of conscious and automatic retrieval more generally to one of *intent*: When subjects are not attempting to actively use previously studied information to complete the task, then retrieval is deemed automatic. Automatic retrieval likely establishes a substantial substrate of information upon which conscious retrieval processes operate. Thus, even when we make a conscious attempt at retrieval of a previously studied event, automatic processes likely contribute both to the identification of potential strategies and elicitation of mnemonic information about the targeted event (Horton et al., 2001).

This definition has a number of implications. First, speed of responding is not a theoretical requirement for establishing the use of automatic retrieval: Rather, automatic retrieval is an integral component of conscious retrieval rather than sequestered from it. Nonetheless, the value of our speeded response task is that it allows us to *exclude* the use of conscious retrieval, as indicated by the RT data we have reported here and elsewhere. Second, this definition is silent in terms of the occurrence of unintentional conscious awareness (e.g., Richardson-Klavehn et al., 1996) following automatic retrieval. Although most if not all automatic *processes* may be transparent and inaccessible to awareness, the *products* of those automatic processes may normally be fully accessible to awareness. Indeed, our definition requires the latter conclusion if in fact automatic processes are integral to conscious (or intentional) retrieval. For example, no matter what conscious processes we invoke, we may not be able to access the underlying processes and information database that allow us to identify whether an item was previously studied, any more than it is possible to consciously identify the information used to remember the names of our siblings, or the capital of France. Whether we are confident about the episodic history of an item or not, the event either has a sense of familiarity to it (perhaps because we can remember details or it just "feels" familiar) or it does not: What leads to that sense of familiarity may be outside of our conscious grasp.

5.2. Comparisons of automatic estimates

With evidence that our speeded response group provides a relatively pure measure of automatic retrieval, we compared target completion rates on this task with those from a standard implicit memory task and with automatic estimates from a PDP task. The results were consistent in showing that the implicit group provided an accurate estimate of automatic retrieval: There were no differences in target completion rates for the implicit and speeded response groups (see also Horton et al., 2001; Vonk & Horton, in press; Wilson & Horton, 2002). These findings suggest that, within the parameters of our procedure, implicit instructions on the stem completion task may normally be sufficient to avoid contamination with conscious retrieval, at least with stems that are readily completed with several very familiar responses. As most implicit memory studies with the stem completion task use stems with these characteristics, we suggest that performance in those studies plausibly reflects the effects of pure automatic retrieval (Moscovitch, Goshen-Gottstein, & Vriezen, 1994). However, stems with fewer and less accessible completions, or implicit tasks that involve more problem solving strategies (e.g., fragment completion—Mandler, 1991), may yield a different pattern of target completion if a conscious retrieval strategy becomes more efficient compared to a pure automatic retrieval strategy. Together, these conclusions suggest that the focus of the retrieval intentionality criterion (Schacter et al., 1989) on implicit versus explicit instructions will sometimes, but not always, permit a distinction between the use of automatic and conscious retrieval processes.

By contrast to the implicit group, estimates of automatic retrieval from the PDP task yielded a different pattern. In conditions that allowed for greater conscious retrieval (semantic encoding in Experiment 1, full attention in Experiment 3), estimates of automatic retrieval were reliably lower in the PDP task than in the speeded response task (Wilson & Horton, 2002). In conditions that spawned lower conscious retrieval (nonsemantic encoding in Experiment 1, long study and test lists in Experiment 2, divided attention in Experiment 3), estimates of automatic retrieval did not differ between the two measures. A target completion rate below baseline was evident in the semantic condition of Experiment 1. This is acknowledged as a signature of a generate/recognize strategy (Bodner et al., 2000) in which subjects do not adopt direct retrieval but rather first use the test cue to generate response alternatives and then use a recognition process to select studied items from the generated alternatives. This strategy implies redundancy rather than independence as all conscious recognition decisions are based on automatically generated response alternatives. Notably, this pattern was not evident in Experiment 3. Nonetheless, the pattern of conscious and automatic estimates in the PDP groups was identical across experiments.

The comparison of automatic estimates from the speeded response group with those from the PDP procedure yielded results that were consistent with the hypothesis that automatic and conscious retrieval are positively correlated. Estimates of automatic retrieval based on PDP were similar to those from the speeded response group when *C* was relatively low, specifically when subjects engaged in a nonsemantic orienting task (with shorter lists) or a divided attention task. By contrast, when *C* was relatively high, such as when subjects engaged in a semantic orienting task or studied under conditions of full attention, PDP tended to underestimate automatic retrieval (see also Bodner et al., 2000; Russo et al., 1998; Wilson & Horton, 2002). However, these data do not provide an unequivocal test of the independence assumption that is central to PDP.

The PDP makes the further assumption that awareness of the episodic history of a retrieved item maps uniquely onto conscious retrieval processes (Kinoshita, 2001; Reingold & Toth, 1996). If this ''awareness assumption'' (Horton et al., 2001) is incorrect, such that the episodic history of retrieved items can be obtained through automatic retrieval (Dodson & Johnson, 1996; Richardson-Klavehn, Gardiner, & Java, 1994, 1996, 1999), it would still be possible, in principle, for the two *retrieval* processes to be independent. However, when assuming independence, violation of the awareness assumption will result in an underestimation of *A* (and an overestimation of *C*).

An alternative interpretation of performance on the inclusion and exclusion tasks is that subjects engage in a generate/recognize rather than a direct retrieval strategy. Bodner et al. (2000) have shown that the ''signatures'' of a generate/recognize strategy need not be present, even when subjects are given generate/recognize instructions. Indeed, they reported data from this condition that mimicked performance under direct retrieval instructions. However, since a generate/recognize strategy assumes the version of the redundancy model that we have adopted here, our data are not entirely supportive of this interpretation: Estimates of automatic retrieval based on the redundancy assumption were somewhat higher than those from the speeded response group, at least under conditions of relatively high conscious awareness. This implies that subjects in the inclusion and exclusion groups were able to use conscious awareness to enhance performance beyond that provided by automatic retrieval.[2]

We add one qualification to this conclusion that there is not strong evidence of a generate/recognize strategy in the inclusion and exclusion tests. Such a strategy suggests an iterative process of identifying potential targets followed by a recognition check on each generated item. However, the speeded response group was asked to provide just the first item that came to mind. Thus, we may not have exhausted the potential output of automatic retrieval processes as might occur when subjects are encouraged to repeat the generation process until they come up with a target or they reach their self-defined criterion for terminating the search.[3]

Although other interpretations are possible, our data and those of Jacoby (1998) are consistent with this type of iterative generate/recognize strategy. Horton et al. (2001) reported that the explicit group completed more stems with studied items in the semantic encoding condition than did the speeded response group. Similarly, when Jacoby's (1998) direct retrieval group performed an inclusion task following a full attention study task, they too completed more stems with targets than did the generate/recognize group who simply generated the first word that came to mind. If our explicit instructions and Jacoby's direct retrieval instructions induced an iterative generate/recognize strategy (not an unreasonable assumption given that the goal of both groups is to output a studied word), then the higher target completion rate in these groups compared to groups asked to use the first word that comes to mind (our speeded response group, Jacoby's generate/recognize inclusion group) is readily explained. This finding should occur whenever subjects can consciously identify at least some targets and the probability of generating the target on the first attempt is less than unity. In principle, though, it is still possible that subjects given an inclusion task under direct retrieval instructions actually engage in direct retrieval as conceptualized within PDP and that this direct retrieval itself is iterative.

5.3. Criterial task differences

Automatic estimates from the speeded response procedure and from the implicit memory task consistently differed from those from the PDP conditions, except when conscious estimates in the PDP conditions were low. Although some of the criticisms of PDP may ultimately contribute to an explanation for this outcome, we would like

[2] Mike Masson suggested that the inclusion and exclusion instructions may have induced a generation strategy that increased the number of studied items that were actually generated, relative to that of the speeded response group. Weldon and Colston (1995, Experiment 2) showed evidence for such a difference in a comparison of implicit and explicit instructions on a stem completion test, although under conditions that appear to more closely resemble those used in our study, this difference was not reliable (Horton et al., 2001). Our data do not provide a basis for discriminating these alternative interpretations.

[3] Another possibility is that the retrieval of multiple items may be simultaneous, or nearly so. However this would seem to have no net effect on the interpretation, as presumably the conscious process of evaluating each alternative would still be serial. Again we thank Mike Masson for raising this issue.

to raise another possibility. In the speeded response procedure and in implicit memory tasks, subjects are instructed to respond with the first word that comes to mind. By contrast, the inclusion and exclusion instructions used in PDP experiments specify that subjects use the test cue to respond with a studied or a nonstudied word, respectively. Clearly the criterial task (Jenkins, 1979; see also Bodner et al., 2000: McBride, Dosher, & Gage, 2001; Snodgrass, 2004; Whittlesea & Price, 2001) differs in these two situations and this difference might be expected to influence the processing that subjects enlist. Yonelinas (2002) noted that the differential emphasis on speed could also affect these processes, although we consistently find no differences in target completion rates between the speeded response procedure and standard implicit tasks. Thus, conclusions about automatic retrieval based on implicit memory performance and performance on the speeded task may be accurate for this type of criterial task (no attempt to retrieve studied words) whereas conclusions about automatic retrieval based on PDP tasks may be accurate for that type of criterial task (intentional retrieval of studied words) (see Mecklenbräuker, Wippich, & Mohrhusen, 1996, for a similar view; see also Jacoby et al., 1993; Neumann, 1984).

Certainly our ideas about the effect of different criterial tasks run counter to the way some researchers think about automatic processes, namely that they are insensitive to the goals and purposes of the subject (see Besner, Stolz, & Boutilier, 1997, for examples of this view; Kelley & Jacoby, 1998). Is there any evidence that automatic retrieval processes vary across experimental situations? Besner et al. (1997) provided an example using the Stroop task. When congruent items were eliminated from the design such that there was no support for engaging in automatic retrieval of the word itself, interference in the incongruent condition was totally eliminated. Thus, the way in which subjects approached the test affected automatic retrieval of the word (see also Besner, 2001).

5.4. *Procedural issues*

The key feature of the direct retrieval hypothesis is that subjects engage independent automatic and conscious retrieval processes simultaneously upon presentation of the test cue. For this reason, PDP instructions advise subjects to use the test cue to retrieve a studied item (Jacoby, 1998). However, it is further argued that it is desirable to manipulate inclusion and exclusion tests within rather than between subjects as we have done here (see also Buchner et al., 1995; Dodson & Johnson, 1996; Jacoby, 1991; Jacoby et al., 1993; Russo & Andrade, 1995). One reason for this prescription is that a within-subjects design may minimize differences in response bias across tests (Yonelinas & Jacoby, 1996; but see Richardson-Klavehn & Gardiner, 1998). However, a between-subjects design does not *de facto* produce such changes, as is evident in the present results. A second reason is that data from a between-subjects design resist analysis because of the lack of an error term for automatic estimates. The procedure we have described for estimating the variance of a ratio (Horton & Vaughan, 1999) resolves this concern. The question remains, then, whether there are reasons for preferring a within- rather than a between-subjects design for inducing direct retrieval.

In PDP studies, subjects are instructed to use the test cue to "recall" a studied item and then to base their response on the inclusion and exclusion tests on that recall (Jacoby, 1998). This appears to be the essential feature of the test instructions for inducing a direct retrieval strategy. We suggest that the instruction to use the test cue to "recall" a studied item is as easily incorporated into between- as within-subjects designs.[4] Further, because the between-subjects design does not necessitate discarding data from subjects with exclusion scores of zero, as occurs (sometimes frequently—e.g., Richardson-Klavehn & Gardiner, 1998) in a within-subjects design, the former may actually be preferred. As noted by Curran and Hintzman (1995), discarding data from subjects who are very successful at following instructions (i.e., excluding all studied items) can be a problem as scores are discarded from one end of the distribution only. Such a procedure can be expected to introduce a bias into the estimates of C and A. Thus, there are several reasons why researchers might opt for a between-subjects manipulation of inclusion and exclusion. It remains to be seen whether two design alternatives yield comparable results and, if not, the theoretical implications of such outcomes.

6. Conclusions

The purpose of our research was to compare automatic estimates derived from our speeded response group with those from an implicit memory group and from PDP groups. Given the RT evidence supporting the assumption that subjects in the speeded response group adopted automatic retrieval throughout the test phase, the finding of identical automatic estimates for the speeded response and implicit groups suggests that, under our experimental conditions, the implicit group also employed automatic retrieval. By contrast, the PDP groups consistently revealed underestimates of automatic retrieval when conscious retrieval was high but not when conscious retrieval was comparatively low, suggesting that automatic and conscious retrieval were positively correlated rather than independent. As a consequence of this underestimation, results from the PDP groups suggested that neither depth of processing nor the attention at study manipulation affected automatic retrieval, although a small depth effect was found on automatic estimates in Experiment 2.

[4] The instruction to use the test cue to "recall" a previously presented word appears to be the critical procedural instantiation of direct retrieval (Jacoby, 1998). Thus these instructions provide the basis for satisfying "the assumption that [C] is the same for inclusion and exclusion tests as well as [satisfying] the independence assumption" (Jacoby, 1998, p. 18) and, importantly, for avoiding concerns of subjects engaging in a generate/recognize strategy. To assume that subjects can and will follow these instructions in strict accordance with the direct retrieval model seems a weighty assumption indeed (see also Curran & Hintzman, 1995; Joordens & Merikle, 1993; Russo et al., 1998) and one that requires careful empirical validation. In one attempt to demonstrate the effects of different instructions, Jacoby (1998, Experiment 1) compared these recall instructions with "generate/recognize" instructions. However, labelling standard implicit memory instructions as "inclusion test instructions" and then using the data from this task to derive estimates of C and A (Jacoby, 1998, Appendix B) does not, in our view, provide a strong basis for assessing the efficacy of the recall instructions for satisfying the assumptions of PDP.

In contrast, automatic estimates derived from the standard and speeded response tasks showed that both of these manipulations affected automatic retrieval. These findings suggest caution in interpreting the lack of effect of several variables on estimates automatic retrieval derived from PDP.

Acknowledgement

The first author was supported by a Natural Sciences and Engineering Research Council discovery grant. We thank Colin M. MacLeod, Alan Richardson-Klavehn, and David Vaughan for helpful comments and suggestions on this research.

Preparation of this article was completed in part while the first author was a Visiting Scholar at the Department of Psychology, University of Otago, Dunedin, New Zealand, and at the School of Psychology, Victoria University of Wellington, Wellington, New Zealand. We thank the members of the Departments for their hospitality and generosity.

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